

OPTIMIZATION OF MICRO EDM DRILLING PROCESS USING
TAGUCHI METHOD

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I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

This thesis deals with optimization of micro Electrical Discharge Machining (EDM) drilling process using Taguchi method. EDM is a thermal process that utilizes spark discharges to erode a conductive material. The objective of this thesis is to study the effect of independent variable to accuracy of micro EDM drilling process and to optimize it by using Taguchi method. Taguchi Method is used to find the optimal drilling parameters for hole diameter in drilling operation. The orthogonal array, the signal-to-noise ratio, and analysis of variance are employed to study the performance characteristics in drilling operations of mild steel (50mm length x 75mm width x 5mm height) as workpiece by using 1mm copper (Cu) pipe electrode. Three drilling parameters namely, pulse off time, peak current, and servo standard voltage, are optimized with considerations of hole diameter. It is found that Taguchi's robust orthogonal array design method is suitable to analyze the hole diameter problem. Also parameter design of Taguchi method provides a simple, systematic and efficient methodology for the optimization of drilling process. The result concluded that use of greater pulse off time, greater peak current and medium servo standard voltage give the better hole diameter for the specific test range. The results also significantly reduce the cost and time market and improve product reliability and customer confidence. There are several suggestions that could be implanted as to improve results and obtained more accurate finding. For example, the experiment should be run repeatedly in order to gain more accurately ANOVA table. In addition, further study could consider more factor such as pulse on time, material removal rate (MRR), coolants and etc in the research to see how the factors would affect hole diameter.

ABSTRAK

Tesis ini membentangkan pengoptimuman mesin mikro EDM dengan menggunakan kaedah Taguchi. EDM adalah proses terma yang menggunakan percikan api untuk mengikis bahan keras. Objektif tesis ini adalah untuk mengkaji pembolehubah bersandar terhadap kejituan proses penebukan mikro EDM dan untuk mengoptimumkannya dengan menggunakan kaedah Taguchi. Kaedah Taguchi telah diguna pakai untuk mencari parameter penebukan yang optimum bagi diameter lubang untuk proses penebukan. Susunan orthogonal, nisbah signal-to-noise, dan variasi analisis telah digunakan untuk mengkaji pencirian prestasi dalam operasi penebukan bagi kepingan besi (50mm panjang x 75mm lebar x 5mm tinggi) dengan menggunakan 1mm elektrod kuprum (Cu). Tiga parameter penebukan iaitu, pulse off time, puncak saat, dan servo voltan piawai telah dioptimumkan dengan mengambil kira diameter lubang. Didapati bahawa kaedah Taguchi susunan orthogonal sesuai untuk menganalisis permasalahan diameter lubang disampingkaedah ini juga mudah, sistematik dan metodologi yang effisien untuk mengoptimumkan proses penebukan. Kesimpulanya, dengan menggunakan pulse off time yang tinggi, puncak saat yang tinggi dan medium servo voltan piawai dapat memberikan diameter lubang yang lebih baik untuk spesifik lingkunagn ujian. Keputusan juga berupaya menurunkan kos dan masa ke pasaran, memperbaiki kepercayaan produk dan keyakinan pelanggan. Terdapat beberapa cadangan yang dapat memberikan keputusan yang lebih baik dan jitu. Sebagai contoh, eksperimen hendaklah dijalankan berulang kali untuk mendapatkan kejituan ANOVA. Selain itu, kajian lanjutan yang mengambil kira factor lain seperti pulse on time, material removal rate (MRR), system penyejukan dan sebagainya untuk melihat sama ada factor-faktor ini member kesan terhadap diameter lubang dalam kajian ini,

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LIST OF SYMBOLS

μs	Micro second
μF	Micro farad
mm	Milimeter
A	Ampere
V	Volt
K	Kelvin
SS_T	Total sum of the squared deviations
SS_p	Sum of the squared deviation parameter
SS_e	Sum of the squared deviation error
S_p	Correction sum of squares
p	Parameter
j	Level number
sn_j	Sum of the signal to noise ratio
D_t	Degree of freedom
D_p	Degree of tested parameter
V_p	Variance of the parameter tested
V_e	Variance of the error
F_p	F -value
ρ	Percentage contribution
y	Observed data
\bar{y}	Average of observed data
S_y^2	Variance of y
n	Number of observation
\emptyset	Diameter
$\hat{\eta}$	Signal to noise ratio
η_m	Total mean of S/N
$\bar{\eta}_i$	Mean S/N ratio at the optimal level
q	Number of the process parameters

LIST OF ABBREVIATION

ANOVA	Analysis of variance
EDM	Electrical discharge machining
C	Carbon
Cu	Cuprum
CNC	Computer numerical control
DOE	Design of experiment
IP	Peak current
OFF	Pulse off time
S/N	Signal to noise ratio
SVR	Servo standard voltage
TiC	Titanium carbide
TaC	Tantalum carbide
WC	Tungsten carbide

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Electrical Discharge Machining, commonly known as EDM, is a process that is used to remove metal through the action of an electrical discharge of short duration and high current density between the tool or electrode and the workpiece. This principle of removing metal by an electric spark has been known for quite some time. In 1989, Paschen explained the phenomenon and advised a formula that could predict its arching ability in various materials (S.Bigot, 1999). The EDM process can be compared to a miniature version of a lightning bolt striking a surface, creating a localized intense heat, and melting away the work surface.

Electrical discharge machining has proved valuable and effective in machining of super tough, hard, high strength and temperature resistance of conductive material. These metals would have been difficult to machine by conventional methods.

In drilling hard, tough, high strength and temperature resistance material, people can not run traditional drilling. Electro discharge machining (EDM-Drill) is one of the best ways in drilling this kind of material especially

in term of getting micro-hole. Material is removed by means of rapid and repetitive spark discharge across gap between electrode and work piece.

The basic physical characteristics of the micro-EDM process is essentially similar to that of the conventional EDM process with the main difference being in the size of the tool used, the power supply of discharge energy, and the resolution of the X-, Y- and Z- axes movement.

Growing popularity of micro EDM depends on the its advantages including low set-up cost, high aspect ratio (depth/diameter ratio) of the holes, enhanced precision and large design freedom. In addition, EDM does not make direct contact between the tool electrode and workpiece material, hence aliminating mechanical stress, chatter and vibration problems during machining. Therefore, relying on the above advantages, micro-EDM is very effective to machine any kind of small holes such as small diameter holes down to 10 μm and blind holes with 20 aspect ratio.

Today, in mold making, EDM no longer can be neglected. In recent years, rapid development of defense industry, telecommunication, entertainment, etc which can't run from producing micro-component such as integrated circuit (IC) component, ink jet nozzle, hand phone chip do really need EDM. Reported by Nexus market analysis, over the next four years, the Microsystems market, including Micro-Structure Technologies (MST) and Micro-Electro-Mechanical Systems (MEMS), is predicted to grow at a rate of 16% per year from \$12 billion in 2004 to \$25 billion in 2009 across a spectrum of 26 MEMS/MST products (NEXUS, 2006). Conventional processes are increasingly being improved for use in micromachining. The most common processes are micro milling, laser machining and more specifically micro EDM, which is being applied in many micro applications.

This project will study the optimal parameter in SODICK EDM micro hole drill in term of machine accuracy on mild steel by using 1mm copper (Cu) pipe electrode. In EDM-drill, most problems faced are, hole accuracy which is crucial element in mould and die construction which play a big role in order to minimize production cost. Talking about optimal parameter, the parameters yet must be select first which consider as control factor which consist of pulse off time (OFF), peak current (IP) and servo standard voltage parameter (SVR).

Taguchi method is utilized in this study as Design of Experiment (DOE) to get optimal parameter. This method is chosen because it can perform analyze of more than one factor at a same time while reducing number of experiment which indirectly reduce cost and time in finding optimal parameter.

1.2 OBJECTIVE OF THE STUDY

The objective that must be carried out by this study in order to get the optimum parameter of EDM micro drill by utilization of Taguchi methods are:

1. To study the effect of independent variable to accuracy of micro EDM drilling process by using 1mm copper electrode.
2. To optimize micro EDM drilling process using Taguchi method.

1.3 SCOPE OF THE STUDY

In order to get the best result, this research must be scoped narrower where it consists of:

- 1 The parameters that to be study are Pulse Off Time (OFF), Peak Current (IP), and Servo Standard Voltage Parameter (SVR).
- 2 This project will study the optimal parameters in SODICK EDM micro hole drill in term of machine accuracy on mild steel (50mm length x 75mm width x 5mm height) as a workpiece by using 1mm copper (Cu) pipe electrode.
- 3 As the analysis tool to determine global solution for the optimal parameter, Taguchi method will be employed by using L₉ orthogonal array.

1.4 PROBLEM STATEMENT

As what world can not deny today, practical is not as perfect as theory which due to large number of variable and the uncertain nature of the process, even highly skilled operator is difficult in archive optimal performance of machining. Even tough likely most EDM machine today have process control, but selecting and maintaining optimal setting is still an extremely difficult job. Machining accuracy of the workpiece is one of the main problems to achieve since this characteristic determine hole accuracy. In order to achieve the objectives, optimum parameter of pulse off time, peak current, and servo standard voltage parameter have to determine where Taguchi method will be employed.

1.5 PROJECT FLOW CHART

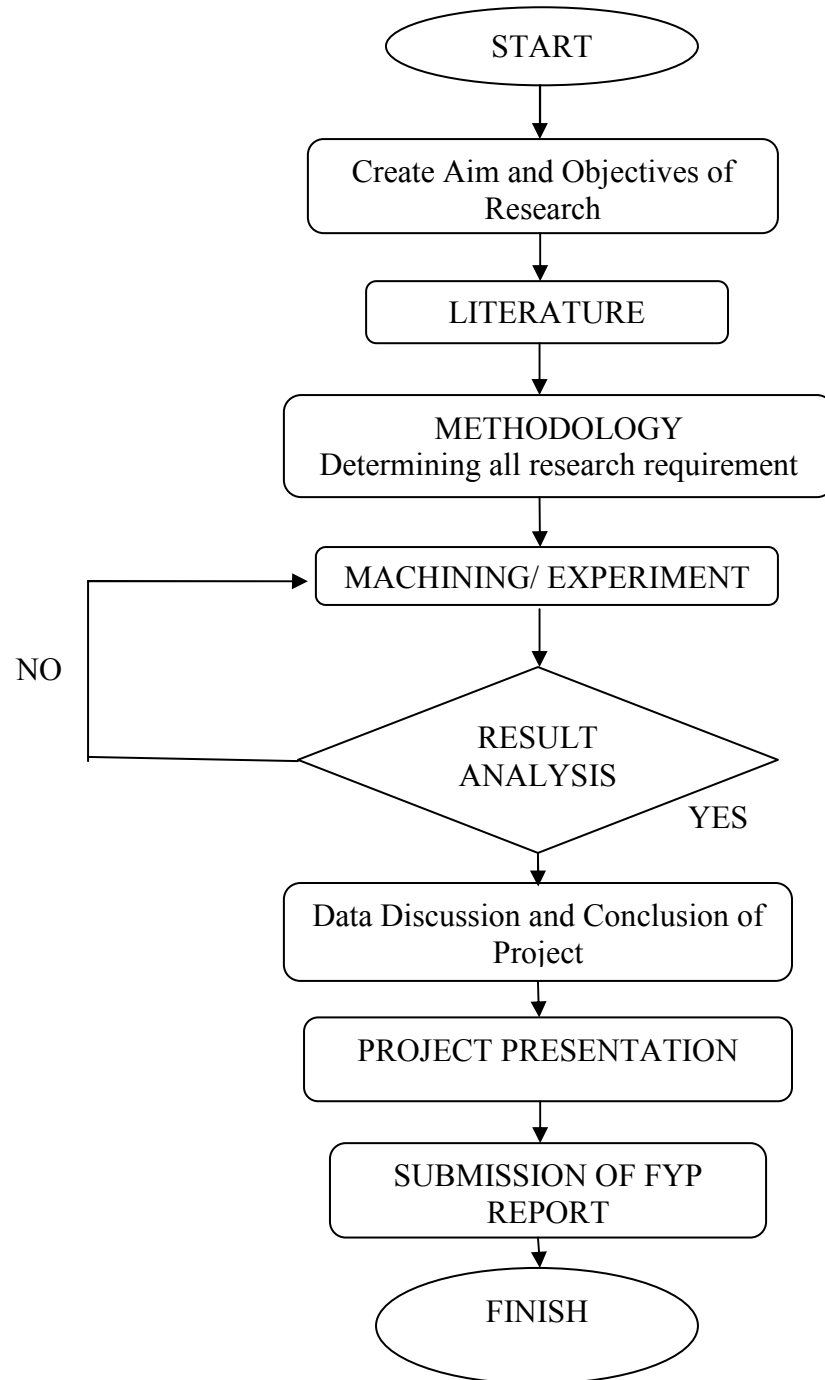


Figure 1.1: Project flow chart

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION TO EDM AND ITS DEMAND IN INDUSTRY

Electrical Discharge Machining (EDM) is a non-contact machining process for conductive materials that has been applied for more than 40 years (D.T Pham, 2004). It has been proved particularly useful such as in mold making, tool making industry micro-structures including micro-shaft, micro-holes, specially shaped micro-holes, and micro-slots. Due to its high accuracy and the good surface quality that it can be produced, EDM is potentially very suitable for micro-fabrication. The EDM process utilizes the thermo-electric energy released between a workpiece and a highly charged electrode. A pulsed electrical discharge across the small gap (known as the “spark” gap) between the workpiece and the electrode removes material from the workpiece through melting and evaporation. Clearly, due to the contactless nature of EDM, there are only very small process forces. This complied with the availability in recent years of advanced computer controlled spark generators such as Sodick® that help improve machined surface roughness, promises to make EDM the preferred method for producing micro features. In order to get clear view of how EDM work, their basic operation is illustrated in Figure 2.1.

Day to days, the markets demand of small and compact product such as microchip in computer, handphone, electrical part in car, accurate fuel injection nozzle, surgery equipment and other micro electro-mechanical system has been increase significantly. That is why we need to study on how to make micro component such as micro hole more efficient, low production time as long as low manufacturing cost. This project is a study on how to get optimum parameter of EDM drill in order to drill small hole on rectangular solid mild steel by utilization of Taguchi method.

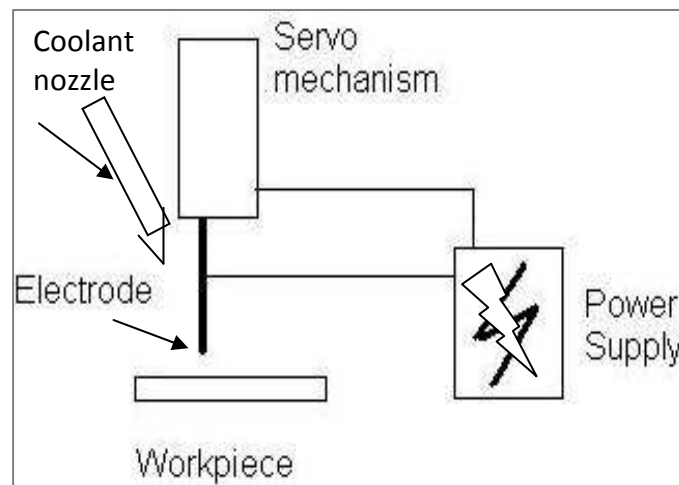


Figure 2.1: Schematic diagram of EDM-drill

2.2 PROBLEM FACED IN EDM DRILL

Traditionally, small or micro hole will be done by skilled machinist by using a sensitive drill but this technique is hard to operate and cause broken tool. Broken drill and scraped part may lead this process as expensive operation since micro drill tool is a costly product. However, as the process of

drilling by EDM-drill is more relevant, somehow electrode price is expensive. That is why electrode wear must be set as minimum as possible. One thing we should know is that, even electrode price is high but it is still lower compare to other machining tool. One more problem in EDM-drilling is when wrong parameter is set, the electrode will tend to retract up and down position continuously, which cause the hole won't be drill though. Even tough getting optimum parameter in EDM is a hard process but, with proper DOE technique such as Taguchi, the process becomes easier.

2.3 INTRODUCTION TO EDM PARAMETER

Electrical discharge machining parameter can be categorizing into two major group; electrical and non-electrical parameters (S.H Lee, 1999). The electrical parameter consist of electrode polarity, peak current, pulse duration, and capacitance meanwhile, non-electrical parameter are servo parameters such as gap and gain. For the EDM machine itself can be spread into four main components which are a machine tool, power supply, servo computer and servo mechanism. However, the parameters that we going to study are pulse on time, peak current and capacitance.

2.3.1 Machining Voltage, V

One of the components of EDM-drill is power supply. This is one of important system where it transform the AC supply from main power to provides rectangular voltage pulse as illustrated in Figure 2.1 .The AC source is converted by rectifier to DC source. The voltage is usually in range of 40 to 400Volts. The sequence of the rectangle is a graphic representation of the opening and closing of the switch, or can be simplify as the pulse duration and

pulse interval, or of the discharge time and pause, also of the voltage and current at the spark gap.

2.3.2 Peak Current, I_P

Peak current is momentary maximum current to be placed to discharge gap or in easy word, peak current is best defined as the highest electrical current that can occur during the discharge. This is the amount of power used in discharge machining, measured in unit of ampere, A. The discharge current is proportional to the height of the rectangle as shown in Figure 2.2 below.

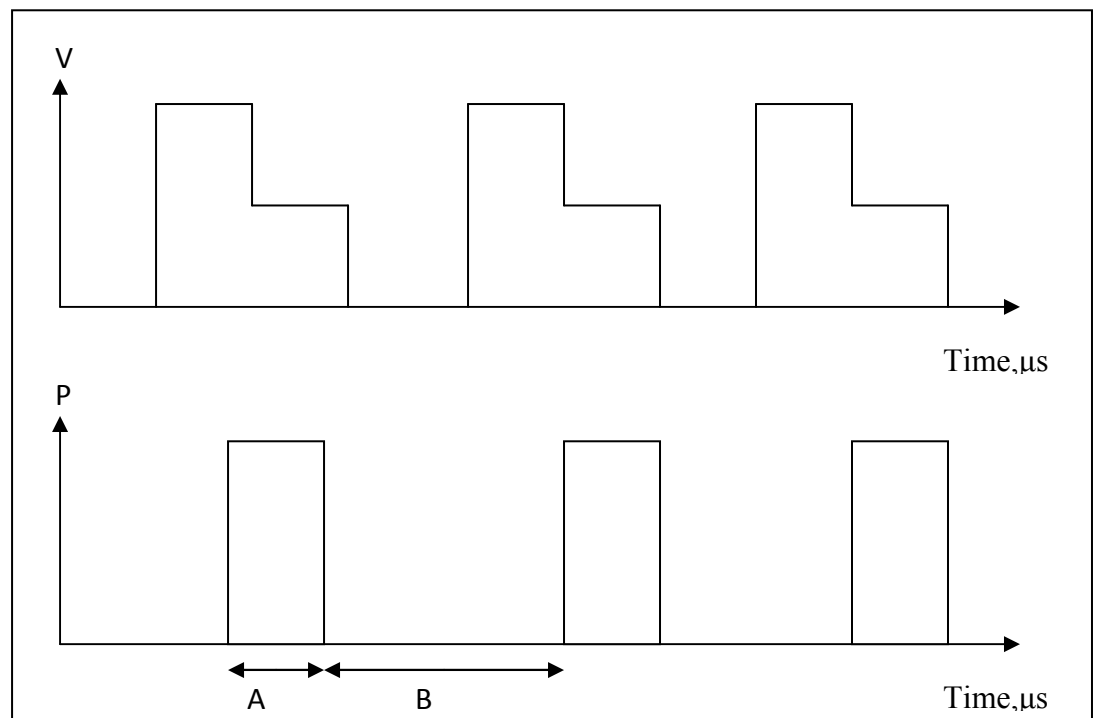


Figure 2.2: EDM electrical parameter characteristic

V = Machining Voltage

P = Peak current

A = Pulse duration (spark)

B = Interval time (time that current is switch off)

2.3.3 Pulse-off Time, OFF

The time between two impulses is call pulse-off time. While most of the machining takes place during on time of the pulse, the off time during which the pulse rests and the re-ionization of the die-electric takes place, can affect the speed of the operation in a large way. This parameter also measured by μs . Longer the off time will cause longer machining time. But this is an integral part of the EDM process and must exist. The Off time also governs the stability of the process. An insufficient off time can lead to erratic cycling and retraction of the advancing servo and result slowing down the operation cycle.

2.3.4 Servo Standard Voltage, SVR

It is important that there be no physical contact between the electrode (tool) and the workpiece; otherwise arcing will occur, causing damage to both the electrode and the workpiece. That is why servo mechanism is very important. This system will automatically maintain constant gap of approximately 0.01 to 0.02 mm between the electrode and workpiece. The mechanism also advance the tool into the workpiece as the operation progress, and sense and correct any shorted condition by rapidly retracting and returning the tool. Precise control of gap is important to obtain successful machining operation. The mechanism of servo parameter is actually a set of parameter that determine the standard voltage to be used as the reference; When the gap voltage is greater than this value, the electrode advances; when